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A STUDY OF THE ISALLOHYPTIC CENTERS AT THE 500 MB LEVEL

M. B. MORELAND

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M. B. Moreland

A STUDY OF THE TENDENCY OF ISALLOHYPTIC CENTERS AT THE 500 MB LEVEL

by
Milton Bruce Moreland
Lieutenant, United States Navy

Submitted in partial fulfillment
of the requirements
for the degree of
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the thesis requirements for the degree of

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PREFACE

The purpose of this research was, if possible, to find a forecasting tool for the tendency of the isallohyptic centers at the 500 mb level. This study started by investigating the relative motion of centers of warming or cooling and the isallohyptic centers, but naturally led to investigating other variables which might influence the isallohyptic centers.

This work was carried out at the U. S. Naval Postgraduate School, Monterey, California during the first half of 1952.

I wish to express my appreciation to Associate Professor Frank L. Martin of the Aerological Engineering Staff for the many helpful suggestions and guidance given during this project.

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TABLE OF SYMBOLS AND ABBREVIATIONS

mb	Millibar
r	Correlation coefficient
X_1	Tendency of isallohyptic center at 500 mb
X_2	Tendency of temperature change center at 500 mb
X_3	Relative east-west motion between isallohyptic centers and temperature-tendency center
X_4	Relative north-south motion between isallohyptic centers and temperature-tendency centers
X_5	Time rate of change of actual distance between isallohyptic centers and temperature-tendency centers
X_6	Rate of change of temperature-tendency following the isallohyptic center
X_7	The advection of isotherms at the center of the isallohyptic center
X_8	Relative motion of the temperature-tendency center along the path of the isallohyptic center
Z	Zebra or Greenwich meridian time
T	Temperature
t	Time
H	Height
$\frac{\partial}{\partial t}$	Local time variation operator of the property considered
$\frac{\delta}{\delta t}$	Individual time rate of change operator following a closed center. With a subscript H indicates the values following the isallohyptic center
∇	Differential vector operator
$\mathbb{C}$	Vector velocity of system considered

$\frac{\partial T}{\partial t}$	Local temperature change or the temperature-tendency
$\frac{\partial H}{\partial t}$	Local height change or height tendency
Δ	Time difference of property considered
x	East-west distance between tendency centers
y	North-south distance between tendency centers
D	Actual distance between the tendency centers regardless of direction
D'	Distance between tendency centers along the path of the isallohyptic center
p	Pressure
$\mathbb{V}$	Vector wind velocity

I. INTRODUCTION

Due to the many new developments in aircraft which necessitate their operating at greater altitudes, the field of Aerology has started to use and to prognosticate the wind patterns at these higher elevations. The object of this project was to find forecasting tools to help in prognosticating these upper-level charts.

The 500 mb level was selected because it is fairly representative of the mean of the atmosphere. Also, it is near the level of non-divergence and has fewer closed centers than most other levels. However, it is not so high that the reports become too scarce.

This investigation was suggested by a paragraph in a pamphlet by Riehl [4]. He was speaking about isallohyptic analysis and makes the following statement:

> Experience with this method of analysis is as yet very limited. It is conceivable, however, that it could be developed into a potent aid for forecasting both at sea level and 500 mb. It appears of particular interest to conduct a study that investigates the relative motion of pressure change centers and centers of warming or cooling.

One method of prognosticating the 500 mb chart is the time differential, where the prognostic pattern obtained depends upon the direction and speed at which the isallohyptic centers are moved and upon their changes in intensity. Mansueto [3] found a definite correlation between the movement of the isallohyptic rise centers at 700 mb and the 500 mb flow. However, for the isallohyptic fall centers the results were negative. His method could be extended to

the isallohyptic centers at the 500 mb level to obtain their movement. This paper deals with the change in the intensity of the isallohyptic centers. This change is actually the tendency of the isallohyptic centers.

After performing the differential analysis on a series of charts to get the isallohyptic centers, the position and intensity of the center during its life cycle were plotted on a separate chart. By using this track of the center, and subtracting intensity of the center at time zero from the intensity at time zero plus twelve or twenty-four hours later, the twelve or twenty-four hour tendency was obtained.

The first investigation carried out in this study was to find the effect of the relative motion between the temperature-tendency centers and the tendency of the corresponding isallohyptic centers. This in turn led to investigating the effect of several other variables on the tendency of the isallohyptic centers, i.e., the tendency of the temperature-tendency centers, the tendency of the temperature following the isallohyptic center, and the effect of the advection of isotherms in the isallohyptic centers.

The part of the investigation dealing with the relative motion of the centers did not yield significant results. However, several of the other correlations were significant and it is believed that they could prove of value as a forecasting aid.

Being able to forecast more accurately the intensity of the isallohyptic centers should result in a better prognostic 500 mb chart. This in turn should lead to a better surface prognostic chart.

This investigation was carried out on a purely statistical basis with no dynamic or kinematic principles involved.

II. SELECTION OF AN AREA AND A SEASON FOR STUDY

The geographical area selected for this investigation was from the southern boundary of the United States to 60 degrees north latitude and the east and west coast of North America between these latitudes. This area was chosen because the reporting network is denser and the reports more reliable than those of other sections of the globe. Also, the reports are filed more consistently. This is an important factor in the time differential method since it is desirable that there be no gaps in the data during the research period.

The period selected for the investigation was during the months of November and December of 1950. The winter season was chosen, because the troughs and ridges are more distinct during this period. This in turn would result in more marked isallohyptic centers and make it easier to track the centers from map to map.

All of the radiosonde reports used in plotting the charts were taken from the Daily Upper Air Bulletins [5] and are unedited data.

III. FORMULATION OF THE PROBLEM

1. The Variates To Be Considered.

The following variates were defined and used during the course of this study:

(a) The tendency of the isallohyptic center, X_1.

$$X_1 = \frac{\delta}{\delta t}\left(\frac{\partial H}{\partial t}\right)$$

The variable $X_1 > 0$ if the center has a rising tendency.

(b) The tendency of the temperature-tendency center, X_2.

$$X_2 = \frac{\delta}{\delta t}\left(\frac{\partial T}{\partial t}\right)$$

The variable $X_2 > 0$ if the center has a rising tendency.

(c) The time rate of change of the relative east-west positions of the temperature-tendency centers with respect to the isallohyptic centers, X_3.

$$X_3 = \frac{\Delta x}{\Delta t}$$

The variable $X_3 > 0$ if the temperature-tendency center is moving eastward with respect to the isallohyptic center.

(d) The time rate of change of the relative north-south positions of the temperature-tendency centers with respect to the isallohyptic centers, X_4.

$$X_4 = \frac{\Delta y}{\Delta t}$$

The variable $X_4 > 0$ if the temperature-tendency center is moving northward with respect to the isallohyptic center.

(e) The time rate of change of the actual distance between the temperature-tendency center and isallohyptic center regardless of direction, X_5.

$$X_5 = \frac{\Delta D}{\Delta t}$$

The variable $X_5 > 0$ if the centers are closing.

(f) The time rate of change of the temperature-tendency following the center of the isallohyptic system, X_6.

$$X_6 = \frac{\delta}{\delta t_n}\left(\frac{\partial T}{\partial t}\right)$$

The variable $X_6 > 0$ if the temperature-tendency at the center of the isallohyptic system rises.

(g) The "advection" of isotherms at the center of the isallohyptic system, X_7.

$$X_7 = \mathbf{C} \cdot \nabla T$$

(h) The time rate of change of the relative displacement of the tendency centers, along the path of the isallohyptic system, X_8.

$$X_8 = \frac{\Delta D'}{\Delta t}$$

The variable $X_8 > 0$ if the centers are closing.

The temperature variable was used so extensively, because a great deal of the time a forecaster has better indications of the temperature changes than pressure or height changes. Moreover, the studies of pressure-change mechanisms and of vertical motion of Fleagle [1, 2] suggest a possible correlation between temperature change and pressure change.

2. Method of Performing the Time Differential.

The period chosen for obtaining tendency charts for both height and temperature was twelve hours.

On a single chart, say for 0300Z, the temperature and height of the 500 mb level at 0300Z were plotted immediately adjacent to each station. Next, just below the 0300Z reports, the same values for the previous 1500Z reports were plotted. The next step was to perform an algebraic subtraction on the two temperatures and two heights. The resulting value obtained was the twelve hour tendency of the variable concerned, namely, $\frac{\partial T}{\partial t}$ and $\frac{\partial H}{\partial t}$ at each particular station for the period ending at 0300Z. By drawing isolines of temperature and height changes the centers of rising or falling height, called isallohyptic centers and centers of local warming or cooling, called temperature-tendency centers were obtained.

The above operation yielded the distribution of two variables, $\frac{\partial T}{\partial t}$ and $\frac{\partial H}{\partial t}$. These centers were then tracked at twelve hour intervals for as long as the center could be positively identified as the same entity from map to map.

3. The Relative Motion Between the Twelve Hour Tendency Centers.

It was decided to use two methods of determining the relative motion between the isallohyptic centers and the temperature-tendency centers. Both were easily adapted to linear correlation with the variate X_1.

The first method was to use the latitude lines as the x axis and longitude lines as the y axis. Using this coordinate system, the relative motion was broken up into the x and y components, x being positive eastward and y being positive northward. The position of the isallohyptic centers and temperature-tendency centers were plotted on a separate chart throughout the life cycle of the systems at twelve-hourly intervals. Now from this track the variates X_3, X_4 and X_5 were obtained by merely subtracting the distance between temperature-tendency centers and the isallohyptic centers at time zero plus twelve hours from the distance between the two centers at time zero.

The second method required the use of the variate X_8. This was obtained by using the path of the isallohyptic center as one axis of a coordinate system and measuring the motion of the temperature center relative to it. The variate X_8 is that component of the relative motion of the tendency centers which is along the path taken by the isallohyptic center.

4. Method of Obtaining Variates X_6 and X_7.

The variate X_6 was obtained simply by subtracting the local variation of the temperature $\left(\frac{\partial T}{\partial t}\right)$ at the center of the isallohyptic system as shown on the differential analysis at time zero plus twelve hours from the same value at time zero.

The variate X_7 was obtained from the equation for the individual change, i.e., $\frac{\delta T}{\delta t} = \frac{\partial T}{\partial t} + \mathbf{C} \cdot \nabla T$, where $\mathbf{C}$ is the velocity of

the isallohyptic center, $\frac{\delta T}{\delta t}$ is the observed temperature change in twelve hours following the center of the isallohyptic system, $\frac{\partial T}{\partial t}$ is the value of the temperature tendency at the beginning of the twelve hour period. While, $\mathbf{v}\cdot\nabla T$ is what is actually meant by advection, it was felt that $\mathbf{c}\cdot\nabla T$ might afford a "measure of advection" or at least give a good forecast variate for the isallohyptic tendency. The first two terms of the equation were readily available from the charts upon which the time differential was performed. Thus, the remaining term $\mathbf{C}\cdot\nabla T$ could easily be obtained by substitution in the equation for the individual change.

5. General Remarks.

It should be noted that all tendencies employed are twelve hourly values. The investigation was first carried out using the twelve hour rate of change of these tendencies. However, this line of attack yielded negative results. It was felt that the diurnal contribution in the twelve hour rate of change of tendency was responsible for the negative results. Therefore, in order to eliminate this diurnal influence from the rate of change of tendency, the twenty-four hour rate of change of tendency of the isallohyptic center was noted. A similar procedure was employed for the rate of change of temperature tendency. This proved to be advantageous and led to several significant results.

At the beginning of the investigation it was decided to treat the isallohyptic falls and rises separately. This procedure was followed throughout.

Simple linear regression equations were formed for any of the variates which had a correlation coefficient greater than 0.50.

The results will be summarized in the following chapter.

IV. RESULTS AND CONCLUSIONS

This project has involved an analysis of a subject on which very little could be found in the literature. Therefore, certain arbitrary rules had to be formulated. First in dealing with the isallohyptic centers, it was decided to carry out the differential analysis at intervals of fifty feet to get the value at the center. For the temperature-tendency centers, the units were degrees centigrade and the interval was one degree centigrade.

The results of that part of the investigation dealing with the tendency of the isallohyptic center as affected by the relative displacements between this center and the temperature-tendency center yielded completely insignificant results. For example, see correlation coefficients in Table 1, page 12.

In trying to improve the results, the second coordinate system, which employed the path of the isallohyptic center as the abscissa, was devised. However, correlating X_8 (the twenty-four hour rate of change of relative distance between the tendency centers) with X_1 (the twenty-four hour rate of change of the isallohyptic fall centers) gave a correlation coefficient of -0.1031 which was not significant. Therefore the analysis was not carried out for the isallohyptic rises nor for the relative motion component perpendicular to the abscissa for the isallohyptic falls.

Simple Correlation Coefficients $r(X_1, -)$ *

	Isallohyptic rises	Isallohyptic falls
X_3	0.0513	0.0013
X_4	-0.1857	0.1445
X_5	0.1919	0.0082
X_3 (24 hour time rate of change of X_1 and X_3)		0.0487

Statistics for the relative displacement of tendency centers for 12 hour rate of change of tendencies, except as noted

TABLE 1.

Overall the results obtained working with the isallohyptic rises for both the twelve and twenty-four hour changes of the variables, and the isallohyptic falls for the twelve hour rates of change were not significant. This may be observed by examining Table 2, page 13.

*In $r(X_1, -)$, the dash indicates the simple correlation is taken with respect to X_1 and the variate appearing in the same row in the Table.

Simple correlation coefficients $r(X_1, -)$
for 12 hour time rate of change of variates

	Isallohyptic rises	Isallohyptic falls
X_2	0.2740	0.4010
X_6	0.1768	0.4487
X_7	-0.0558	0.1810

For 24 hour time rate of change of variates

X_2	0.0328	
X_6	0.2526	
X_7		-0.0777

Statistics for both 12 and 24 hour time rate
of change of tendencies

TABLE 2.

A possible explanation for the less significant results obtained in the cases of isallohyptic rises may be found in a paper by Fleagle * [2] in his Figures 1-6. In his Figures 1, 3, 5 are shown typical cases of rising pressure at 8 kilometers, and also at the 500 mb level. Note that his first two cases, Figures 1 and 2, are associated with cold advection in the stratosphere and downward motions, that is, opposing tendencies insofar as the pressure tendency is concerned.

*Journal of Meteorology, December 1948, p. 286-287

In the third case, Figure 5, both warm advection and downward motion are occurring at the 500 mb level, but not above. Now barring non-adiabatic effects, we have

$$\frac{\partial T}{\partial t} = -\mathbf{v}\cdot\nabla T - w(\gamma_d - \gamma)$$

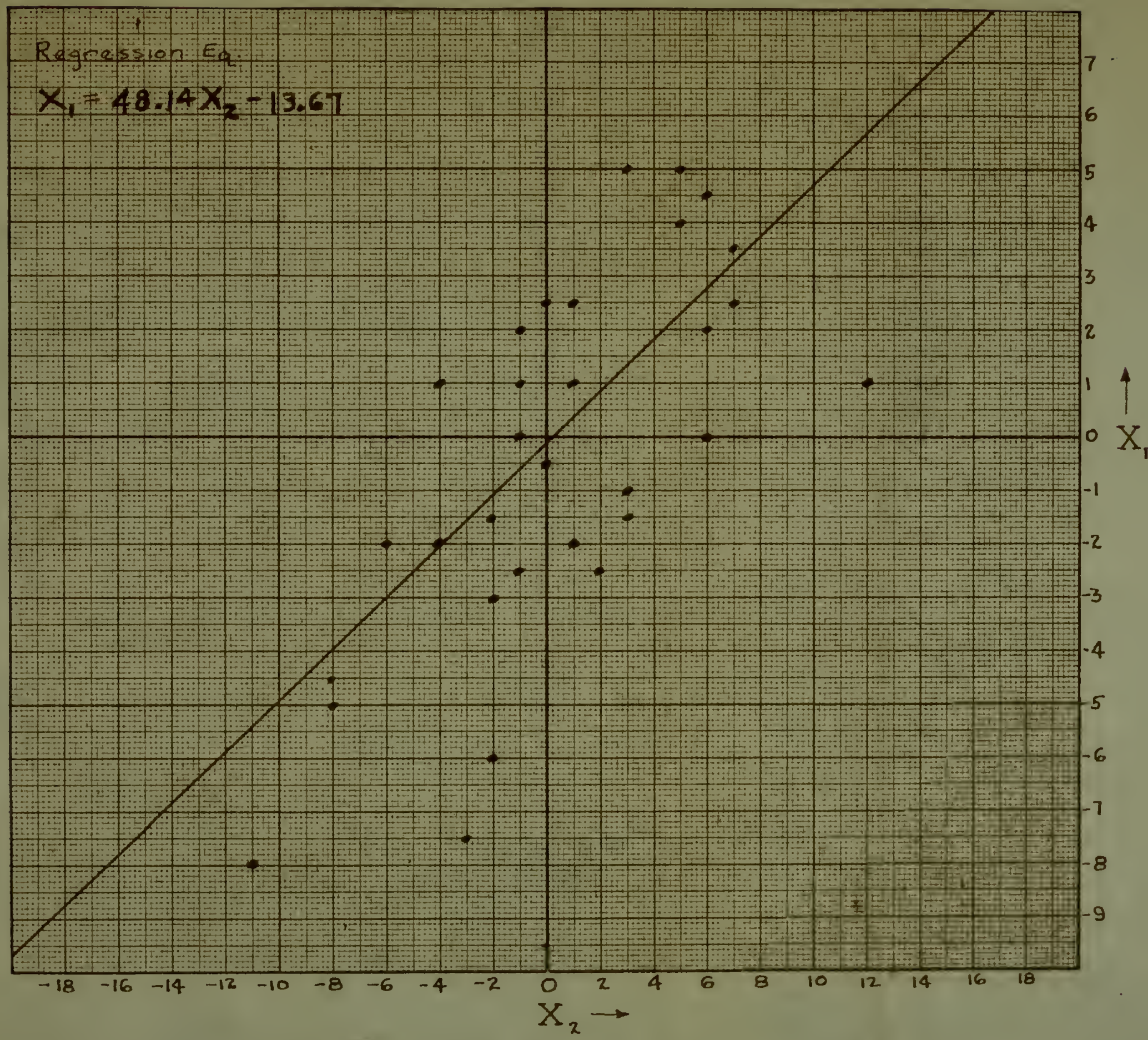
where w is the vertical motion (positive upward), γ_d is the dry adiabatic lapse rate and γ the lapse rate. It follows that when at 500 mb, cold advection exceeds downward motion $\frac{\partial T}{\partial t} < 0$, and conversely $\frac{\partial T}{\partial t} > 0$. However, an additional factor p depending on the local compressional term must be considered in determining the actual density tendency and therefore the pressure tendency.

This additional factor p does not appear in the temperature-tendency. Comparatively, however, it represents a smaller percentage in the low stratosphere so conceivably this is where a strict correlation of $\frac{\partial p}{\partial t}$ and $\frac{\partial T}{\partial t}$ would work best, including also the time variations of each. It would be interesting to repeat this test at the 200 mb level to test this theory.

Another reason for the poor correlations is that the approximation to second derivatives by finite differences is rather inaccurate. Furthermore, there was an inherent inaccuracy of perhaps 100 miles in certain cases in locating tendency centers.

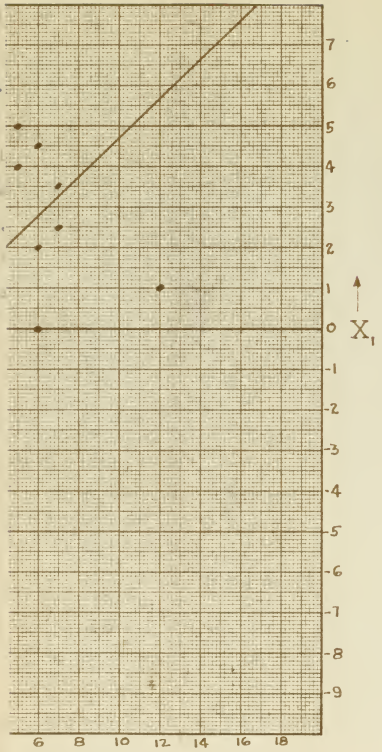
In working with the twenty-four hour tendencies of the isallohyptic fall centers, the correlation of X_1 (the 24 hour tendency of the isallohyptic center) with X_2 (the 24 hour tendency of the temperature-tendency center)

and X_6 (the 24 hour rate of change of the temperature-tendency at the center of the isallohyptic center) were significant. The correlation coefficients were $r(X_1,X_2) = 0.6951$ and $r(X_1,X_6) = 0.6177$. It is felt that even though the correlation coefficients are not so high as to be infallible, they would prove to be a valuable aid in forecasting the tendency of the isallohyptic center. At least, with a good forecast of X_2 or X_6 and using the graphs, Figures 1 or 2, a forecaster would be more apt to go in the right direction (deepen or fill) in prognosticating the tendency of the isallohyptic center.



Scatter diagram and regression line
for variates X_1 (in hundreds of feet) and
X_2 (in degrees centigrade)

Figure 1.



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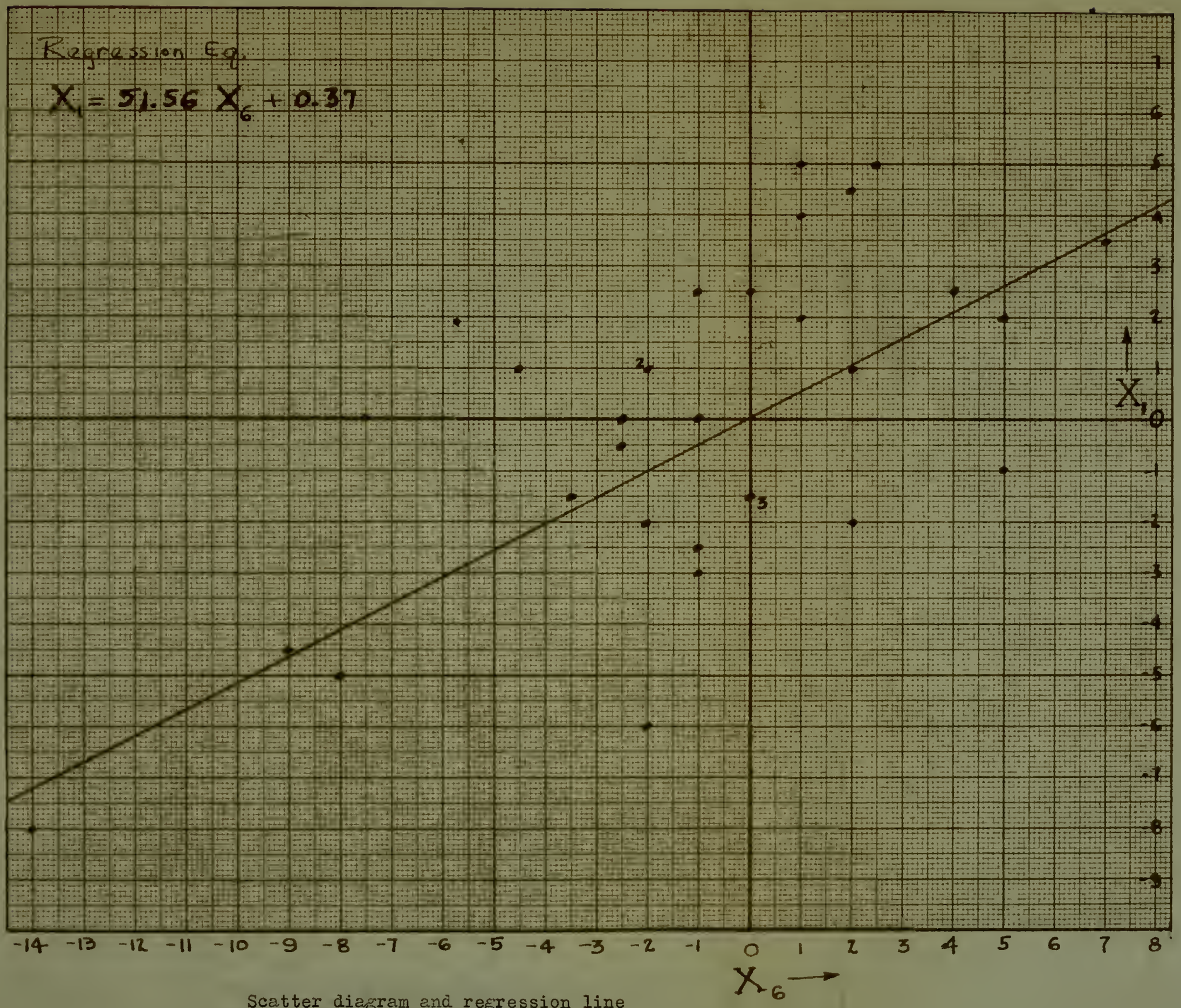
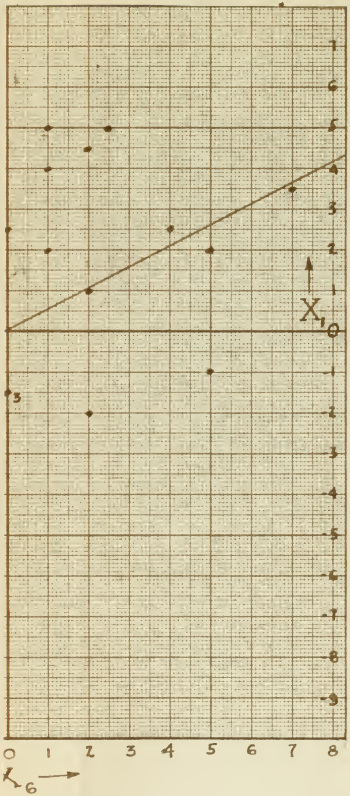


Scatter diagram and regression line
for variates X_1 (in hundreds of feet) and
X_6 (in degrees centigrade)

Figure 2.


7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
X_1
0 1 2 3 4 5 6 7 8
X_6

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1. [illegible]

2. [illegible]

3. [illegible]

4. [illegible]

5. [illegible]

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